may 1959

nlgi spokesman

journal of the national lubricating grease institute

Fitting an Equation to the Flow of Lubricating Greases in Viscometers and Pipes

BY A. W. SISKO, L. C. BRUNSTRUM AND R. H. LEET

Gear Design and Means of Lubrication

BY J. H. ALLEN

How to Get the Motorist to Lubricate for Safety Every 1,000 Miles – From the Service Station Dealer's Viewpoint

BY G. F. LEONARD

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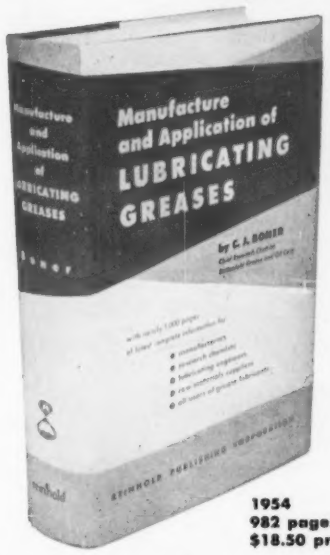
Chief Research Chemist
Battenfeld Grease and Oil Corp.



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13 Strontium Base Lubricating Greases
14 Miscellaneous Metal Soaps as Components of Lubricating Greases
15 Mixed Base Lubricating Greases
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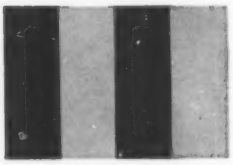

Future Meetings

MAY, 1959

4-6 API Division of Marketing, Lubrication Committee Meeting. San Marcos Hotel, Chandler, Ariz.

15-24 International Petroleum Exposition.

27-29 API Division of Marketing, Mid-year Meeting. The Savery Hotel, Des Moines.

31-June 6 Fifth World Petroleum Congress and Exposition. The Coliseum, New York City.

JUNE, 1959

1-5 Fifth World Petroleum Congress Exposition, The Coliseum, New York City.

8-9 Petroleum Packaging Committee Meeting, Cleveland Ohio.

14-19 SAE Summer Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

21-26 ASTM Annual Meeting Chalfonte-Hadden Hall, Atlantic City, N. J.

AUGUST, 1959

16-21 1959, National Congress of Petroleum Retailers Inc., 13th Annual Session, Jung Hotel, New Orleans, La.

OCTOBER, 1959

26-28 NLGI Annual Meeting, Roosevelt Hotel, New Orleans, La.

11-15 ASTM Committee D-2 Meeting, Sheraton - Palace Hotel, San Francisco.

12-13 Petroleum Packaging Committee Meeting, Port Arthur, Texas

19-21 ASLE and ASME Joint Lubrication Conference, Sheraton-McAlpine Hotel, New York City.

28-30 Society of Automotive Engineers, National Fuels and Lubricants, La Salle Hotel, Chicago.

NOVEMBER, 1959

9-11 API, 39th Annual Meeting, Conrad Hilton, Palmer House and Congress Hotels, Chicago

APRIL, 1960

19-21 ASLE Annual Meeting and Exhibit, Netherland-Hilton Hotel, Cincinnati, Ohio.

APRIL, 1961

11-13 ASLE Annual Meeting and Exhibit, Bellevue Stratford Hotel, Philadelphia, Pa.

OCTOBER, 1961

30-Nov. 1 NLGI Annual Meeting, Edgewater Beach Hotel, Chicago, Illinois.

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NLGI PRESIDENT'S PAGE

By F. E. ROSENSTIEHL, *President*

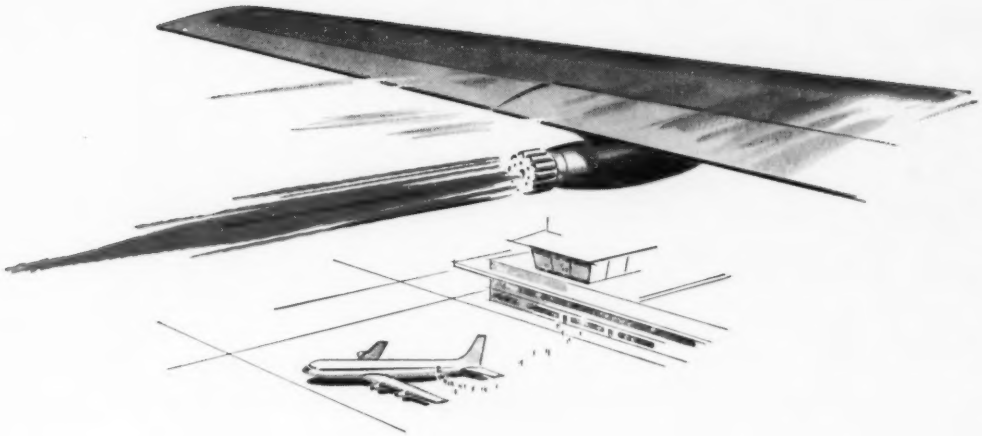
Liaison with the API Lubrication Committee

Those NLGI members who follow the activities of the API Lubrication Committee are familiar with the fact that a concerted petroleum industry effort is being made to educate the motoring public as to the need for more frequent crankcase oil drains. Since crankcase drain and chassis lubrication intervals are companion problems, every effort would also be made to inform the public as to the need for 1,000 mile chassis lubrication.

Insofar as the latter is concerned, all the factors which have so frequently been presented in the past are again being re-emphasized. These include riding comfort, safety, reduction in wear, with resultant savings in parts replacement, etc. Facts gathered to date would indicate that new car dealers are fully conversant with the need for 1,000 mile chassis lubrication.

Accordingly it behooves all of us to get actively behind the API program. Are you and your company doing something effective to increase the regularity of chassis lubrication? Do you know of someone else who is doing an outstanding job in this regard—be he manufacturer of grease, service station operator or new car dealer? If so, tell us about it, since we are constantly exchanging information with the API Lubrication Committee and will be glad to pass the information along to them.

To make the program effective will require the cooperation of all segments of our industry, and I am sure NLGI members can be depended upon to do their utmost in this regard.



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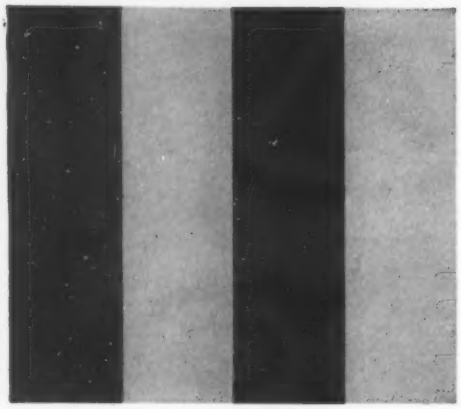
THE COVER

DEPICTED on the cover illustration of this issue are Dr. A. W. Sisko and Dr. R. H. Leet of Standard Oil company (Indiana), operating a new capillary viscometer capable of measuring the viscosity of greases over a wide range of shear rates. Sisko and Leet have co-authored with L. C. Brunstrum, of Standard, the article "Fitting an Equation to the Flow of Lubricating Greases in Viscometers and Pipes" which begins on page 57. This is the second in a series of four fundamental research papers which the NLGI SPOKESMAN is featuring, taken from the October, 1958 convention—first parallel session ever given at an NLGI annual meeting.

The NLGI SPOKESMAN is indexed by Industrial Arts Index and Chemical Abstracts. Microfilm copies are available through University Microfilm, Ann Arbor, Mich. The NLGI assumes no responsibility for the statements and opinions advanced by contributors to its publications. Views expressed in the editorials are those of the editors and do not necessarily represent the official position of the NLGI. Copyright 1959. National Lubricating Grease Institute.



News About NLGI

NLGI Welcomes Three New Members

Three new member firms have been welcomed into NLGI recently, upon approval of the membership committee. The companies and their company representatives include:

United Co-Operatives, Inc., of Alliance, Ohio has affiliated as a Marketing member. Mr. G. E. Castree, manager of the petroleum department is NLGI company representative and Mr. I. R. Slingerland will serve as technical representative.

Werner G. Smith, Inc., of Cleveland has joined as an Associate member, with Mr. Waldemar Meckes, Jr., president, as NLGI company representative.

The Chek-Chart Corporation of Chicago has become a Technical member firm with Mr. Hunt Eldridge, president, as company representative.

The Institute would like to welcome each company and invite them to participate in the many NLGI functions. Special features on the new members, their products, personnel and services, will be presented in later issues of the NLGI SPOKESMAN.

Continued on page 54

SERVICE AIDS

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REPRINTS — From the NLGI SPOKESMAN are available at low cost. Page forms are left standing for three months, company imprint or advertising arranged.

WHEEL BEARING MANUAL— "Recommended Practices for Lubricating Automotive Front Wheel Bearings." More than 120,000 copies of this booklet have been distributed throughout the world. Fifteen cents a copy (NLGI member price) with quantity discounts — company imprint arranged.

VOLUME XXI—Bound volume of the NLGI SPOKESMAN from April, 1957 through March, 1958. Contains 34 articles and features dealing with lubricating greases and gear lubricants . . . $7.00 (NLGI member price) and $10.00 (non-member) plus postage.

VOLUME XXII—Bound Volume of the NLGI SPOKESMAN from April, 1958, through March, 1959. Contains 31 articles and features dealing with lubricating greases and gear lubricants . . . $7.00 (NLGI member price and $10.00 (non-member) plus postage.

NLGI MOVIE — "Grease, the Magic Film," a 16-mm sound movie in color running about 25 minutes, now released. First print $300, second and subsequent orders $200 each (non members add $100 to each price bracket).

BONER'S BOOK—Manufacture and Application of Lubricating Greases, by C. J. Boner. This giant, 982-page book with 23 chapters dealing with every phase of lubricating greases is a must for everyone who uses, manufactures or sells grease lubricants. A great deal of practical value. $18.50, prepaid.

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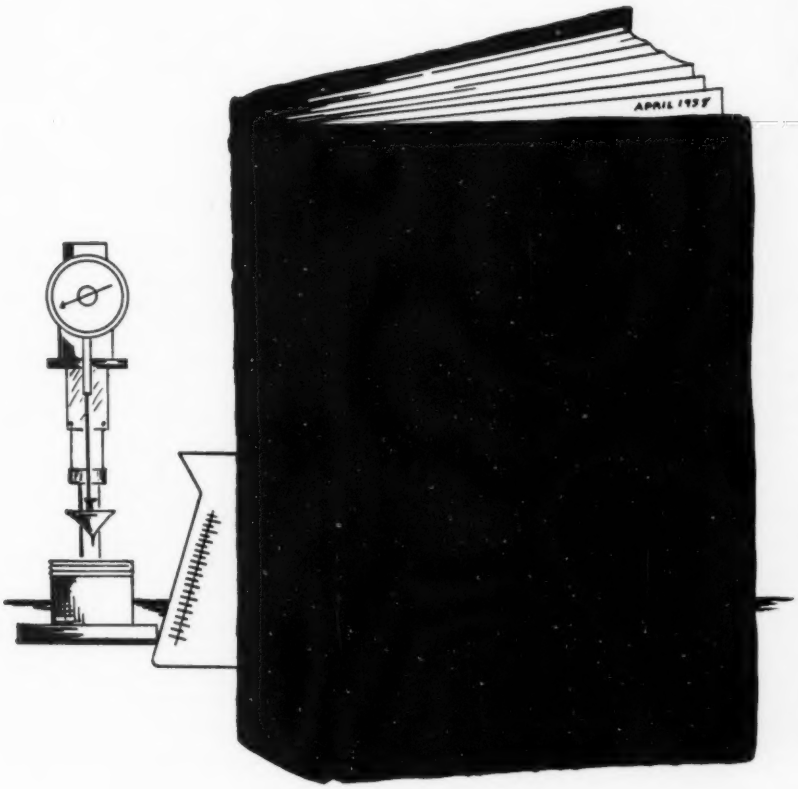

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A. S. Randak Resigns From NLGI Board

Mr. A. S. Randak, company representative of Sinclair Refining company and a member of the NLGI board of directors since October, 1958, has been assigned responsibilities within the firm and has resigned his position on the Institute's governing body. Mr. F. W. Minor has assumed the position of company representative for Sinclair.

Formerly manager of the lubricating sales department, Randak has written for the NLGI SPOKESMAN and been active in the affairs of the Institute. His new position is that of assistant manager of Sinclair's Eastern division.

As provided in the by-laws, the interim vacancy will be filled by the board of directors, until the next election at the annual business meeting.

Second Survey Copies Are Sent to Membership

Copies of the second annual survey on production of lubricating greases and fluid gear lubricants (1958) have been mailed to all categories of NLGI membership . . . reports as furnished by Ernst & Ernst were addressed to company representatives and sent out in mid-April.

The survey was taken from anonymous returns filed with E&E from the Active (manufacturing) members of the Institute and covers production in pounds of lubricating greases as to soap types. Fluid gear lubricants were reported in totals, only.

Distribution beyond the scope of the membership will be discussed at the NLGI board of directors meeting in Chandler, Arizona, in early May.

NLGI Board Meeting

A meeting of the NLGI board of directors will be held at the San Marcos hotel in Chandler, Arizona, on Thursday, May 7. The meeting is adjacent to the meeting of the lubrication committee of the American Petroleum Institute, scheduled for May 4-6 at the San Marcos.

Bound Volume 22 Now Available

Volume XXII of the NLGI SPOKESMAN is now bound and available to readers who desire the journal in book form . . . covering the twelve issues from April, 1958 to March, 1959 the volume is offered to NLGI members for seven dollars and to non-members for ten dollars (plus postage). Immediate shipment can be made upon receipt of order.

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Advantages of Membership

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That the National Lubricating Grease Institute represents over 95 per cent of the lubricating grease industry with members in this country and overseas? The membership list reads like a "Who's Who" in the lubricating grease and allied industries and is proof of the services that NLGI renders to its members.

Some of the advantages of membership are listed below:

NLGI has a Technical Committee of 154 members which is divided into nine sub-committees working constantly on industry problems. These committees are:

Subcommittees on NLGI Classification of Lubricating Greases

Subcommittee on Delivery Characteristics of Dispensing Equiment for Lubricating Greases

Subcommittee on the Procurement of Technical Papers for Publication in the NLGI SPOKESMAN

Editorial Review Subcommittee

Subcommittee on Recommended Practices for Packing Automotive Front Wheel Bearings

Subcommittee on Manual of Test Methods and Definitions of Terms Peculiar to the Lubricating Grease Industry

Subcommittee on Fluid Gear Lubricants

Subcommittee on Fundamental Research

Subcommittee on Manufacturing Procedures and Equipment

Beginning with the production of lubricating grease for the year of 1957, NLGI is instituting a survey which can be of practical value in establishing sales and manufacturing data each year.

The NLGI SPOKESMAN, a monthly technical journal, is mailed free of charge to key personal within a member firm. If extra copies of the magazine are needed, they may be purchased at half the regular subscription price.

The field of gear lubricants is now being covered by NLGI and receives full attention by the organization.

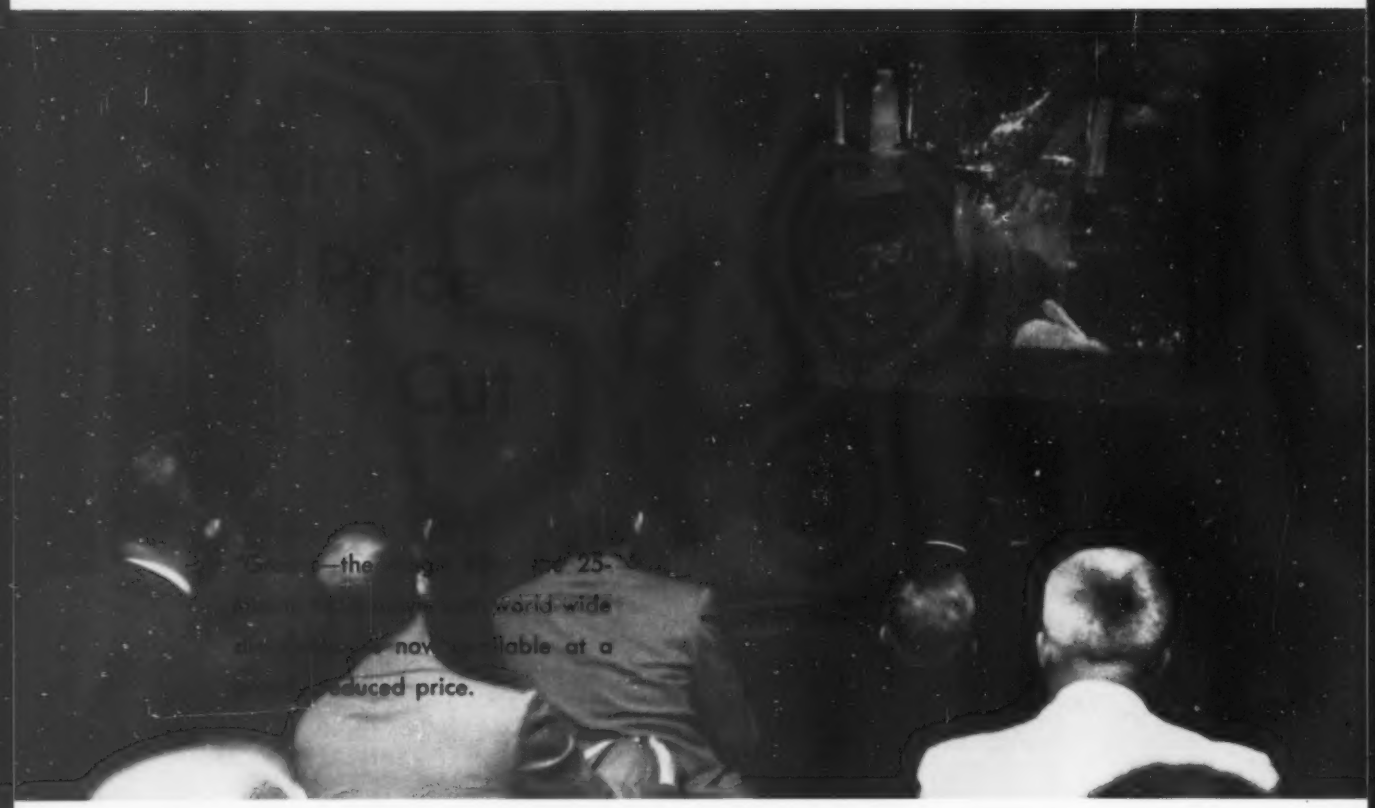
The Institute works in close cooperation with affiliated groups, including SAE, ASTM, ASA, ASLE, ASME, SAE-CIMTC, and IOCA, on problems and accomplishments in the lubricating field.

The Annual Meeting is the highlight of the year and is usually held during the last week in October. It is a three-day session where papers are presented of unusual interest on technical advances, marketing problems, new developments by suppliers and packagers, and the needs of the consumers. Members of NLGI are allowed a substantial discount on registration fees at this meeting.

Recently NLGI completed production on a new movie entitled "Grease, the Magic Film" which is available at $300 for the first print, $200 for the second print and subsequent prints.

The main objectives of the National Lubricating Grease Institute are for the development of better lubricating greases for the consumer and better grease lubrication engineering to industry.

If your firm is interested in becoming affiliated with NLGI, the national office will be happy to furnish further information concerning the organization. Just as 1958 was a banner year for NLGI accomplishments, 1959 promises to be even better with more scope and more member advantages. ■



Members and friends of the National Lubricating Grease Institute are now in a position to employ a vital selling and public relations tool at greatly reduced cost . . . as announced (NLGI SPOKESMAN, April) before, the cost of "Grease –the Magic Film" has been reduced.

The 25-minute movie was produced and subsidized by the Institute to tell the story of lubricating grease. With sales now double the initial estimate, the board of directors reduced the cost of first prints from $600 to $300, while second and all subsequent prints were priced from $400 to $200. The third price category was discontinued (non-members still add $100 to each category).

Illustrated in 16 mm color with narration and sound, the picture begins with animated sequences tracing the early uses of lubricating greases, on into modern movie sequences of application, development, testing, etc., in scenes ranging from military and commercial, to farm and home, to grease plant and laboratory. Airplanes, automobiles, trains, farm machines and contractors' equipment are among the many examples shown and discussed. Steel mill and refrigeration needs are shown, as well as the problems of dust, dirt, and water.

"Grease–the Magic Film" now has a world-wide audience and where needed, can be supplied with stripe for foreign voice narration, complete with script. Many firms have employed the picture as an aid in their program to step up their drive on telling a proper lubrication story and to halt the declining lube ratio. A number of companies use the film as a public relations tool, giving viewings to interested school audiences. Where a member firm feels that the picture could stress a certain phase of lubrication more thoroughly, some companies have shot their own sequences and spliced these scenes into their copy of the movie.

"Grease–the Magic Film" may be purchased through the national office of NLGI and delivery can usually be made within two weeks of receipt of order. A preview copy of the picture may also be obtained from NLGI upon request, along with scripts if foreign voice narration is anticipated.

Fitting an Equation to the Flow of Lubricating Greases in Viscometers and Pipes

By: A. W. Sisko, L. C. Brunstrum and R. H. Leet
Standard Oil Company (Indiana)

Presented at the NLGI 26th annual meeting in Chicago, October 1958

Fundamental Research—2

Abstract

The flow of lubricating grease over the wide shear-rate range of 10^{-3} to 10^{4} reciprocal seconds can be simply and accurately described by the equation

$$F = a\dot{s} + b\dot{s}^n$$

where F is the shearing stress; $\dot{s}$ is the rate of shear; and a, b, and n are constants for each grease. Because these constants characterize a grease and are easily calculated, they should also be useful for correlating with other properties and for writing specifications.

The equation has been successfully applied to data from capillary viscometers, a cone-and-plate viscometer, and pipes. It adequately fits the extensive data of Summers-Smith. Calculated velocity profiles show the typical plug-flow behavior of grease and fit the profiles measured by Mahncke and Tabor.

Pressure drops in a 1.5-inch pipe twenty feet long agree well with the calculated values. For greases that soften as a result of flow, pressure drops can be calculated by modifying the equation to include time as a parameter.

Introduction

The usual way of determining the viscosity of lubricating grease is by means of the ASTM viscometer (1). Results are expressed as log-log plots of apparent viscosity vs. shear rate. This mode of representing flow data leaves much to be desired. Curves that diverge or cross are not readily compared. A given grease cannot be characterized by a number or num-

bers that might also be used for comparison with other grease properties. There is no simple way of denoting the thixotropic nature of some greases. Finally, the range of shear rate is too narrow. A simple equation that would fit the data over a wide range of shear rate would go a long way toward increasing the usefulness of viscosity measurements.

Several equations have been proposed to describe grease flow (3). Notable are those of Buckingham (2) and of Ree and Eyring (9). Both can be fitted to data in the shear-rate range of the ASTM viscometer. However, neither has gained general acceptance because fitting is difficult and because neither has been fitted successfully to the wider range of shear rates found in practice.

An equation (10) that simply and accurately describes the flow of grease over a wide range of shear rate has been described to relate either the shear stress, F, to nominal shear rate, $\dot{s}$,

$$F = a\dot{s} + b\dot{s}^n$$

or the apparent viscosity, η_a, to shear rate:

$$\eta_a = \frac{F}{\dot{s}} = a + b\dot{s}^{n-1}$$

In either form of the equation, a, b, and n are constants for each grease.

For the equation to have practical significance, it must fit data from both capillary and rotational viscometers, and the constants must apply to such engineering problems as flow in pipes. To test its validity, flow data were obtained over the shear-rate range of 10^{-3} to 10^4 reciprocal seconds. Both types of viscometers were used. Data on both shear-stable and thixotropic greases were fitted to the equation, and it was applied also to published data.

Experimental

Four viscometers were used in the course of this work. The capillary instruments were a modified ASTM viscometer, a pipe viscometer, and a new viscometer of wide shear range. The rotational instrument was a cone-and-plate viscometer.

The ASTM viscometer was modified by the addition of a second pump and two larger capillaries. The pumps, operating either singly or in parallel, provide three flow rates through each capillary. The additional larger capillaries extend the shear-rate range of the instrument to one reciprocal second.

The pipe viscometer is a twenty-two-foot length of 1.5-inch pipe equipped with a pressure diaphragm and gauge two feet from the inlet. Grease is fed to the pipe from a stirred pressure vessel holding five gallons. The flow rate is controlled by the vessel pressure and measured exactly by weighing the timed discharge from the pipe. This viscometer was operated to overlap the low-shear-rate range of the modified ASTM viscometer.

The new capillary viscometer of wide range was so designed as to overcome the inconvenience of operating the pipe viscometer. It consists of a multispeed drive, hydraulic cylinder, sample cylinder, and capillaries. Pressure is measured in the hydraulic oil by strain gauges. Hydraulic oil and sample are separated in the sample cylinder by a floating piston. Three capillaries give a shear rate-range of 0.02 to 40,000 reciprocal seconds.

The cone-and-plate viscometer is the Ferranti-Shirley instrument (7) equipped with an extra-large cone for measuring viscosity at low shear rates.

Both the ASTM and the new viscometer were operated by measuring pressures at fixed flow rates, whereas the pipe viscometer was operated by measuring flow rates at fixed pressures. In all three instruments, the shear rate varies from zero at the center to a maximum at the wall. For this reason, Poiseuille's equation, applied to non-Newtonian flow, gives apparent viscosity η_a, nominal shear rate at the wall $\dot{s}$, and shearing stress at the wall F, defined by:

$$\eta_a = \frac{\pi R^4 P}{8LQ} \qquad \dot{s} = \frac{4Q}{\pi R^3} \qquad F = \frac{RP}{2L}$$

where R and L are the capillary radius and length, Q is the volumetric flow rate, and P is the pressure drop across the capillary.

The cone-and-plate viscometer was operated by measuring the torque required to rotate a cone on a flat plate holding the sample. Uniform shearing of the sample permits direct calculation of viscosity η and shear rate g. The method of Krieger and Maron (5) was used to convert the apparent viscosity and nominal shear rate obtained in the capillary instruments to true viscosity and shear rate as obtained from the cone-and-plate viscometer.

Results were handled as log-log plots of apparent viscosity versus nominal shear rate, for the ASTM and pipe viscometers, and of viscosity versus shear rate, for the cone-and-plate and new capillary viscometers. The first pair were directly compared by testing a calcium-soap grease of No. 1 grade in both instruments; the second pair, by testing a No. 2 lithium-soap grease.

Fitting the Equation

To fit the results from the four viscometers, the equation was used in the form

$$\eta_a = a + b\dot{s}^{n-1}$$

To determine the constants b and n, a plot was made at low shear rates where the value of a is negligible. In this range, the plot is linear on log-log paper and may be written

$$\log \eta_a = (n-1) \log \dot{s} + \log b$$

The slope of the line is (n-1), and b is the value of η_a where $\dot{s} = 1$. The value of a was found by comparing the observed values of η_a with those calculated from the equation. Alternatively, the constants may be determined by the method of averages (4).

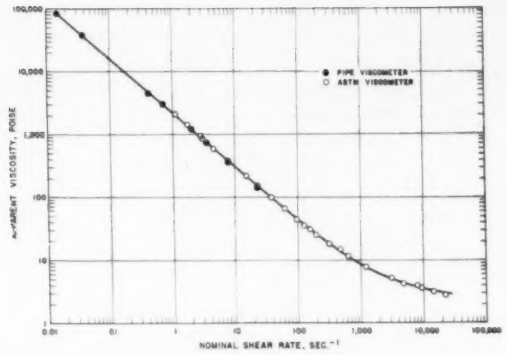


FIGURE 1, fit of equation to flow of calcium grease

Figure 1 compares data from the ASTM and pipe viscometers with the calculated curve. The shear-rate range is 0.015 to 22,000 sec^{-1}, and the results from the two instruments overlap from 1 to 25 sec^{-1}. The constants for the grease are: a = 2.70, b = 2240, and n = 0.139. Agreement between the observed data and the calculated curve is excellent.

Figure 2 compares data from the new capillary and cone-and-plate viscometers with the calculated curve. The shear-rate range is 0.1 to 40,000 sec^{-1}, and the results from the two instruments overlap almost throughout the range. For this grease, the constants are: a = 5.00, b = 3300, and n = 0.188. Again, the agreement is excellent.

Application to Published Data

The equation was fitted to recent published data in two ways. Data for a sodium-soap grease relating shear stress to equivalent flow rate, $\frac{Q}{\pi R^3}$ were obtained from Summers-Smith. Data for a sodium-calcium soap grease relating velocity to radius, resulting in a velocity profile, were obtained from Mahncke and Tabor (6).

Shear Stress vs. Equivalent Flow Rate

Summers-Smith (11) attempted to fit flow data with the equations of Buckingham (2) and of Powell and

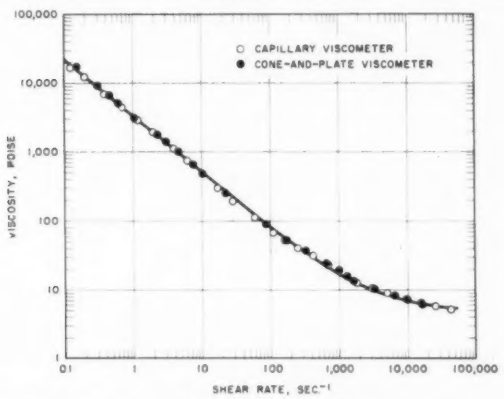


FIGURE 2, fit of equation to flow of lithium grease

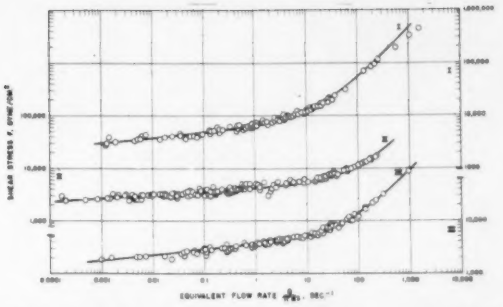


FIGURE 3, application of equation to Summers-Smith flow data

Eyring (8). Neither equation precisely fitted the data.

Figure 3 shows the flow equation applied to a log-log plot of these data. To retain the same coordinates as in the published paper, the equation is expressed in terms of equivalent flow rate and becomes

$$F = a\left[\frac{4Q}{\pi R^3}\right] + b\left[\frac{4Q}{\pi R^3}\right]^n$$

Constants for the three curves are:

	a	b	n
I	111	5,210	0.102
II	13.5	3,790	0.0639
III	20.8	3,090	0.105

The curves calculated from the equation are in substantial agreement with the data. At high equivalent flow rates, they approach the 45° slope of a Newtonian fluid. At low equivalent flow rates, the curves become linear and have slopes greater than zero—as expected from the exponential dependence of the non-Newtonian flow unit. At higher shear rate, energy input raises sample temperature and causes deviations from the calculated values.

Velocity vs. Radius

A photographic study of the velocity profiles developed in greases flowing through tubes has been made by Mahncke and Tabor. The profiles resembled the plug type of flow expected for a Bingham Body. Profiles calculated for a Bingham Body agreed along most of the curve with those observed. The region of disagreement was attributed to an elastic deformation of the face of the moving plug. Because the Buckingham equation, obtained by integrating the Bingham equation for pipe flow, does not fit grease-flow data over a wide range of shear rates, the equation for the velocity profile obtained by integration of the Bingham equation cannot be expected to do so either.

An equation that does fit the velocity profile for this grease can be derived from the new equation. At the low shear rates involved in the photographic study, the Newtonian flow unit is negligible. The shear behavior of the non-Newtonian flow unit predominates. For the non-Newtonian unit, the rate of shear in the capillary, $g = -\frac{du}{dr}$, where u is the velocity at radius r,

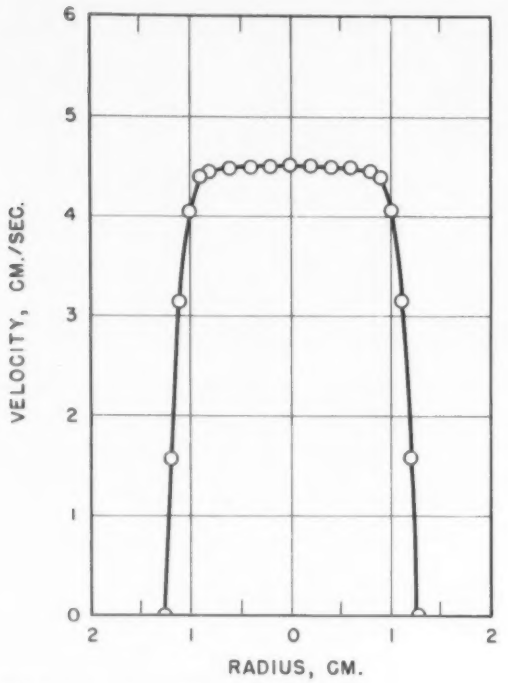


FIGURE 4, fit of equation to profile data

is related to the shearing stress, $F = \frac{rP}{2L}$, at that radius by the expression

$$\frac{rP}{2L} = b\left[-\frac{du}{dr}\right]^n$$

Integrating and applying the condition that the velocity is zero at the wall gives an equation for the velocity at any radius:

$$u = \left[\frac{P}{2Lb}\right]^{1/n} \frac{n}{n+1} \left[R^{\frac{n+1}{n}} - r^{\frac{n+1}{n}}\right]$$

For any given grease at constant flow rate,

$$u = B\,(R^z - r^z)$$

where B and z are constants that are readily found by substituting values of the measured data. The equation found for the data of Mahncke and Tabor is

$$u = 0.450\,(10 - r^{9.63})$$

Figure 4 shows the fit of this equation to the data. The agreement is excellent. It is unnecessary to invoke elastic deformation of the grease to explain the curvature across the face of the plug.

Calculation of Flow in Pipes

Pressure drops in pipes can be calculated for greases that are shear-stable and those that exhibit a change of viscosity during shear. For shear-stable greases, the equation constants are used directly. For greases that show a change of viscosity during shear, a factor is introduced that describes the change in viscosity with time of shear.

For shear-stable greases, the pressure drop in a pipe of length L and radius R is given by

$$P = \frac{2LF}{R} = \frac{2L}{R}(a\dot{s} + b\dot{s}^n)$$

Substituting the expression for $\dot{s}$ gives the pressure drop as a function of volumetric flow rate and the constants for the grease:

$$P = \frac{2L}{R}\left[a\left(\frac{4Q}{\pi R^3}\right) + b\left(\frac{4Q}{\pi R^3}\right)^n\right]$$

Wilson and Smith (12), in a study of the thixotropy of greases, observed a change in the apparent viscosity of some greases produced by flow in a tube. This change was expressed by the equation

$$\eta_a = k\,t_r^h$$

where k and h are constants and t_r is the average length of time the grease resides in the pipe. The constant h is the slope of a plot of log η_a vs. log t_r. An expression for the constant k, derived from the flow equation, yields another equation that can be used to calculate pressure drops in greases that change in consistency as they flow:

$$P = \frac{2L}{R}\left[a\left(\frac{4Q}{\pi R^3}\right) + b\left(\frac{4Q}{\pi R^3}\right)^n\right]\left(\frac{Z}{Z_0}\right)^h$$

Here, Z_0 is the length-to-diameter ratio, L/D, of the capillaries used to determine the flow data (from which the constants a, b, and n were determined) and Z is the L/D ratio of the pipe for which the pressure drop is to be calculated.

The change in viscosity with residence time is shown in Figure 5 for the calcium grease. The viscometer curve is the same as shown in Figure 1. The pipe curve was obtained by considering the grease to

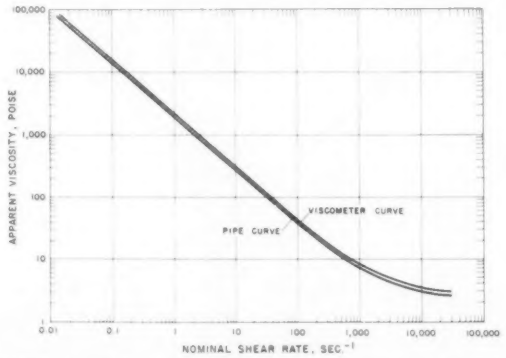


FIGURE 5, application of modified equation to shear softening of grease

be flowing through a pipe having a L/D ratio 1000 times that of the viscometer. The measured value of h for this grease was –0.020. The curve was calculated by substituting into the equation

$$\eta_a = (a + b\dot{s}^{n-1})\left[\frac{Z}{Z_0}\right]^h$$

the values of the constants for this grease. The value of h is based upon observations at intermediate rates of shear (from 4 to 2,000 sec^{-1}) and probably does not hold at higher shear rates where grease flow approaches Newtonian behavior.

Conclusion

In addition to being useful for engineering purposes, the constants a, b, and n characterize the flow behavior of a grease and would be useful in drafting specifications and correlating grease properties. To determine these constants accurately, the shear-rate range of standard grease viscometers should be extended down to at least 1 sec^{-1}.

More work is needed to determine the effects of such factors as temperature, thickener type and concentration, oil viscosity, and particle geometry on the rheological properties of greases. Correlations between these factors and the constants must be sought.

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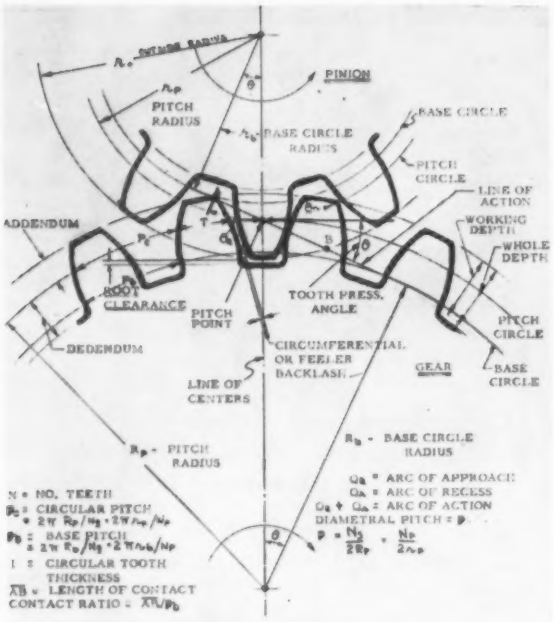
Gear Design and Means of Lubrication



INVOLUTE SPUR GEAR NOTATION

By: J. H. Allen
Farrel-Birmingham Co.

Presented at the NLGI 26th annual meeting in Chicago, October 1958

Abstract

The Coordinating committee of the American Gear Manufacturers Association has been concentrating for some years to prove a formula, common to all gear ratings, is feasible. The committee, according to reports, agree that this condition exists with certain geometry factors added to suit the various types of gears.

The evolution of gear geometry for the past 30 years encompasses a very broad change. Gears made spurs, helical and herringbones ranging from stub and full depth, high and low helix angles are also cut with pressure angles ranging from 14½ to the present 25 degrees. Worm gears of the various types as well as bevels have also had their share of changes with the various methods of tooth finesse such as grinding, shaving and lapping to produce today's highly efficient gearing.

Every gear application properly designed and mounted must also have a properly designed lubrication system to insure its satisfactory operation. Equal importance is given in design that the gears and bearings be properly sized, lubricated and installed, for their long and satisfactory life.

Introduction

Gearing used to transmit rotational motion from one shaft to another belongs to one of two main groups, i.e.

1. Constant velocity ratio gearing.
2. Variable velocity ratio gearing.

Gears manufactured by Farrel-Birmingham belong exclusively to the first, or *constant velocity ratio*, group. In addition, the tooth profiles are formed by involutes of circles, but as shown later the involute shape is not essential for a constant velocity ratio.

Velocity Ratio

The velocity ratio of a pair of gears is the ratio of the angular speeds of the gear shafts. Gear tooth action which produces a constant velocity ratio is termed *conjugate action* and can be obtained with an infinite number of different shapes. In practice, however, only two or three of these are used and one of these, the involute, because of its unique properties, has superseded all others for power transmission gearing.

For a constant velocity ratio a pair of mating gears operating on fixed centers need satisfy only one condition. Figure 1 shows a pair of gears in two successive positions. In both positions the line of action is along a line perpendicular to the tangent common to the gear profiles at their point of contact. The intersection of the line of action and the line of center is termed the *pitch point*. In figure 1A the velocity along the line of action is $V = R_1w_1 = R_2w_2$ where V is in in./sec. and w is in rad./sec., and R_1 and R_2 are radii of the driving and driven gears respectively, perpendicular to the line of action. In Figure 1B, the corresponding velocity is $v=r_1w_1=r_2w_2$. Since the driving angular velocity w_1 is the same for both positions, a constant angular velocity ratio requires that $w_2 = \Omega_2$. If w_2 and Ω_2 are equated, then the lengths along the lines of centers $A = a$, $B = b$ and the pitch points P and p coincide. Thus for a constant velocity ratio, *the common normal to the tooth profiles at their point of contact must pass through a fixed pitch point for all positions of the teeth.*

It is obvious that for any given profile on the driving member a corresponding shape for the driven can be formed which will satisfy the specified condition.

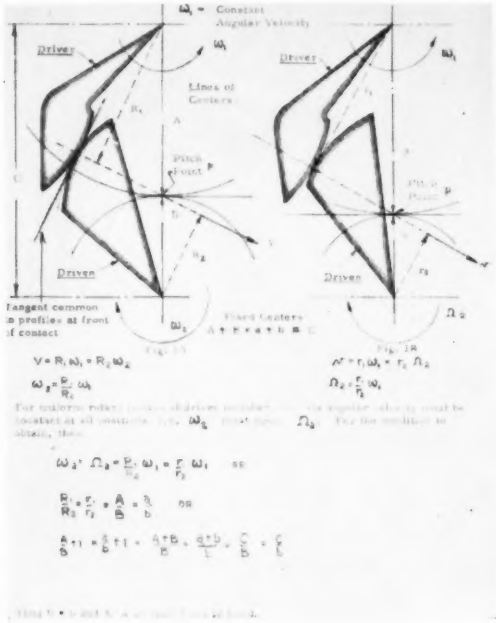


FIGURE 1

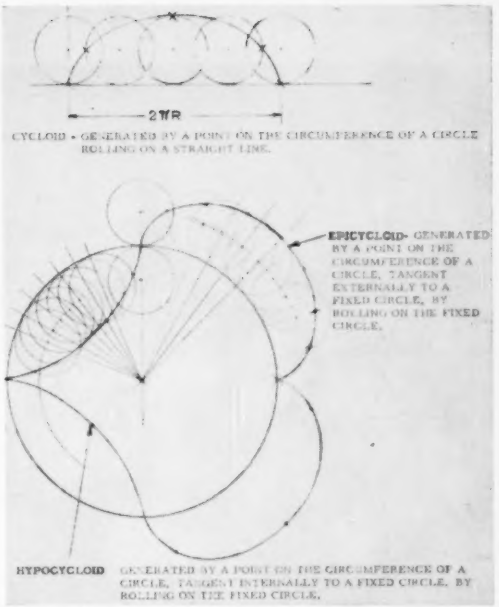

2πR
CYCLOID - GENERATED BY A POINT ON THE CIRCUMFERENCE OF A CIRCLE ROLLING ON A STRAIGHT LINE.
EPICYCLOID- GENERATED BY A POINT ON THE CIRCUMFERENCE OF A CIRCLE, TANGENT EXTERNALLY TO A FIXED CIRCLE, BY ROLLING ON THE FIXED CIRCLE.
HYPOCYCLOID GENERATED BY A POINT ON THE CIRCUMFERENCE OF A CIRCLE, TANGENT INTERNALLY TO A FIXED CIRCLE, BY ROLLING ON THE FIXED CIRCLE.

FIGURE 2

Conjugate Shapes

There are several shapes, other than the involute, which have been used for constant velocity ratio transmission. These are shown in Figure 2, and are the cycloid, the epicycloid and the hypocycloid. Figure 3 shows two mating rotors, or gears, formed by a combination of eip- and hypocycloids where the generating circle is one fourth the size of the pitch circle. It is obvious that the common normal to the point of contact passes through a fixed point. Such rotors are commonly used in positive displacement air blowers. These shapes are included as a matter of interest only and are of no practical importance in so far as gearing of our manufacture is concerned.

A non-involute conjugate rack and gear is shown in Figure 4 to illustrate an important difference between such shapes and the involute. In this case the path of contact is a curve, although the lines of action for all

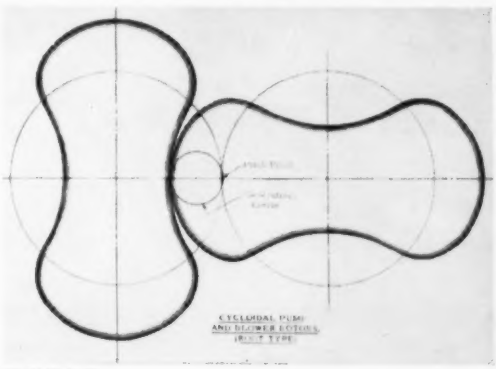


FIGURE 3

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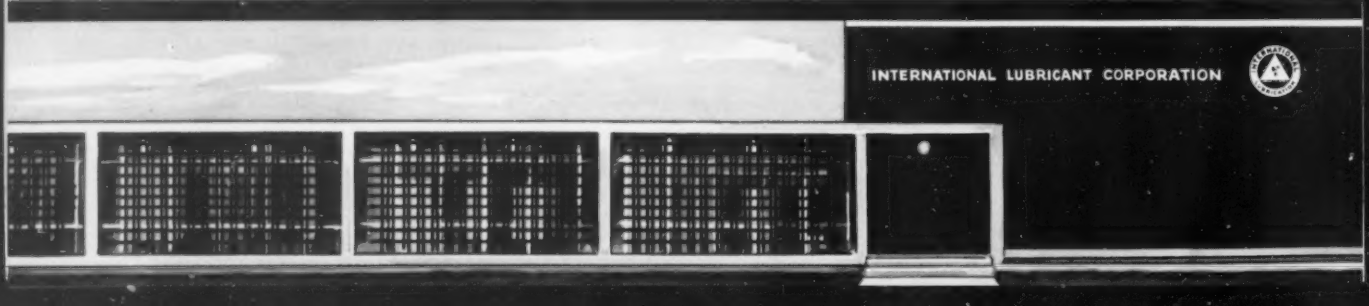

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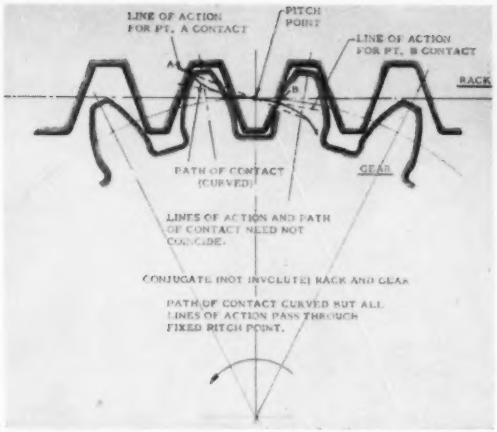

LINE OF ACTION FOR PT. A CONTACT
PITCH POINT
LINE OF ACTION FOR PT. B CONTACT
RACK
PATH OF CONTACT (CURVED)
GEAR
LINES OF ACTION AND PATH OF CONTACT NEED NOT COINCIDE.
CONJUGATE (NOT INVOLUTE) RACK AND GEAR
PATH OF CONTACT CURVED BUT ALL LINES OF ACTION PASS THROUGH FIXED PITCH POINT.

FIGURE 4

positions pass through a fixed pitch point. As will be seen later in involute gears the path of contact and lines of action coincide and are straight.

The Involute

Refer to Figure 5. Suppose that point C on the base circle, of radius R_b, represents the end of a string wrapped around the circle. If the string is unwound and held taut the point C will generate a curve known as an *involute*. The length of the string measured from C to its point of tangency at the base circle is equal to the length of the arc of the circle from the starting to the tangent points.

Further if the string is knotted at equal intervals CD, DE, EF, etc. when unwrapped each knot will generate an involute. In addition, the distance between involutes measured along any tangent to the base circle is *constant*.

Since any smooth curve can be considered as the tangent (or envelope) curve to a series of circular arcs closely spaced together each point of the curve will have a *radius of curvature*. Due to the manner in which the involute is generated the radius of curvature at any point on its profile is equal to the generating tangent; i.e. to a line from the point drawn tangent to the base circle.

The involute tooth is formed by the space contained between two involutes generated in opposite directions from the base circle as shown in Figure 5. The distance on the base circle between the start of successive teeth is termed the *base pitch*.

The *involute angle*, θ is illustrated in Figure 6. Each point of the involute profile is defined by two parameters, i.e., the involute angle, θ and the radius, R from the center of the base circle. The *pressure angle*, φ is the angle formed between the base circle tangent and the perpendicular to the radius R. The relationship between the involute and pressure angles is given by $\theta = \tan\varphi - \varphi$ where θ and φ are in *radians*. Tables are available listing corresponding values of θ, φ and the

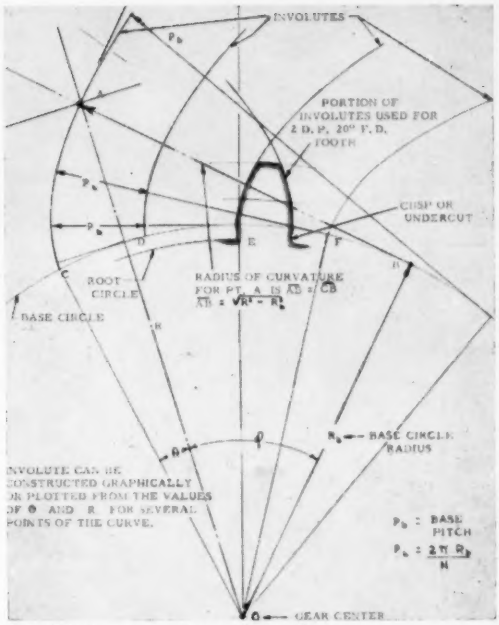

INVOLUTES
PORTION OF INVOLUTES USED FOR 2 D.P., 20° P.D. TOOTH
CUSP OR UNDERCUT
ROOT CIRCLE
RADIUS OF CURVATURE FOR PT. A IS $\overline{AB} = \overline{CB}$
$\overline{AB} = \sqrt{R^2 - R_b^2}$
BASE CIRCLE
R_b — BASE CIRCLE RADIUS
INVOLUTE CAN BE CONSTRUCTED GRAPHICALLY OR PLOTTED FROM THE VALUES OF θ AND R FOR SEVERAL POINTS OF THE CURVE.
P_b = BASE PITCH
$P_b = \frac{2\pi R_b}{N}$
O — GEAR CENTER

FIGURE 5, construction of involute

usual trigonometric functions of φ to seven significant figures. These tables are used in certain phases of gear calculations where high precision is required.

Properties of the Involute

When a pair of involutes are contacted, as in Figure 7, the point of contact lies on the tangent common to the two base circles, regardless of the distance between the centers of the base circles. Since the pressure angle

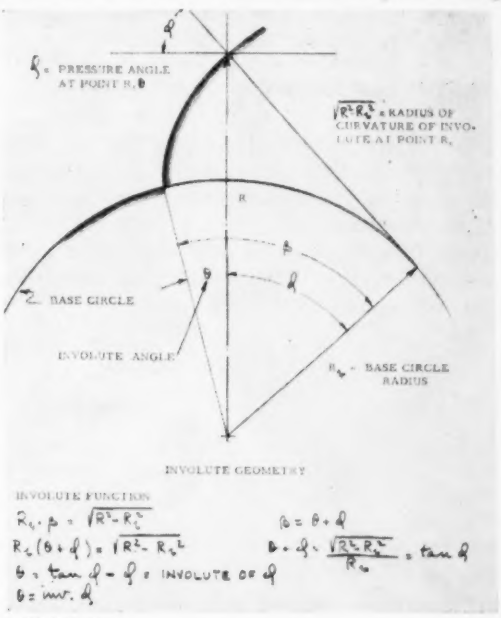

φ = PRESSURE ANGLE AT POINT R, θ
$\sqrt{R^2 - R_b^2}$ = RADIUS OF CURVATURE OF INVOLUTE AT POINT R,
R
BASE CIRCLE
INVOLUTE ANGLE
R_b — BASE CIRCLE RADIUS
INVOLUTE GEOMETRY
INVOLUTE FUNCTION
$R_b \cdot \rho = \sqrt{R^2 - R_b^2}$
$\theta = \theta + \varphi$
$R_b(\theta + \varphi) = \sqrt{R^2 - R_b^2}$
$\theta + \varphi = \frac{\sqrt{R^2 - R_b^2}}{R_b} = \tan\varphi$
$\theta = \tan\varphi - \varphi$ = INVOLUTE OF φ
$\theta = \text{inv. } \varphi$

FIGURE 6

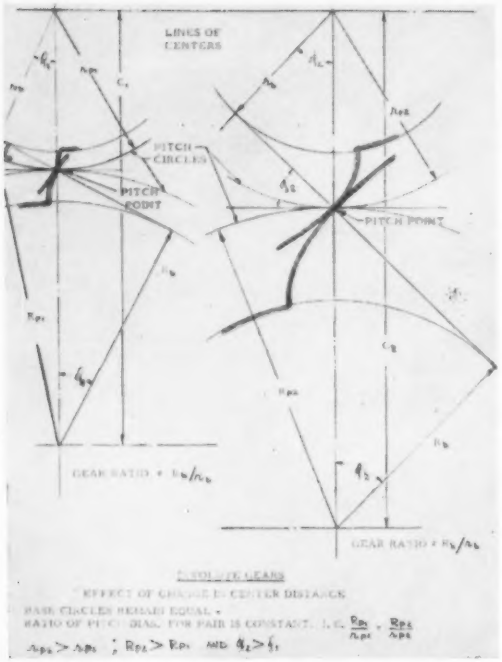


FIGURE 7

is contained between the common tangent and the perpendicular to the line of centers through the pitch point, its value is determined entirely by the sizes of the base circles and the center distance. In Figure 7 the same pair of involutes are contacted at two different center distances, C_1 and C_2, resulting in the pressure angles φ_1 and φ_2. However, the ratio between the radii, Rp_1/rp_1, and Rp_2/rp_2 to the points of contact is the same for both center distances. In other words, the velocity ratio for involute gears is constant regardless of the center distance.

Thus the unique properties of the involute may be summarized as follows:

1. The shape of the involute depends only on the size of the base circle.
2. The velocity ratio of a pair of involute gears is constant regardless of the center distance, and depends only on the ratio of the base circles.
3. The common tangent to the base circles is both the pats of contact and the line of action.
4. The pitch circles and the pressure angle are determined entirely by the center distance used for any pair of base circles. For each center distance there will be a definite set of these three values. Thus we cannot speak of a gear as having a pitch circle or a pressure angle until it is meshed at a specific center distance with a second gear.
5. The form of the basic rack is a straight line, since the rack has a base circle of infinite diameter. See Figure 8.

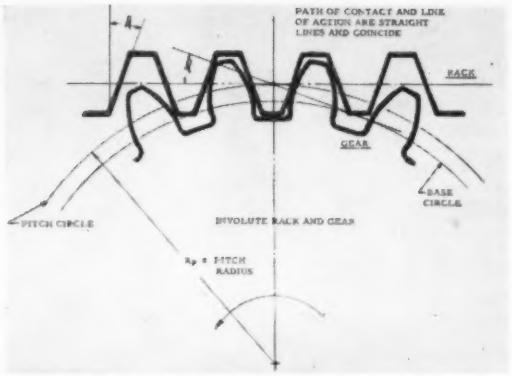


FIGURE 8

6. The involute can be produced much more simply than other conjugate forms.

Tooth action of the pair of involutes during rotation can be studied from Figure 9. This shows a pair of equal base circles, or a 1:1 ratio; and hence during rotation the two circles will move through equal angles in the same time. In Figure 9 the two involute profiles have been divided into lengths corresponding to equal angular intervals on the base circles. Note that the length interval along the profile increases rapidly from the starting point outwards. Thus when the two gears are rotated relative sliding will occur between the two involutes at all positions except when the pitch point and point of contact coincide; in the *latter* position pure rolling occurs.

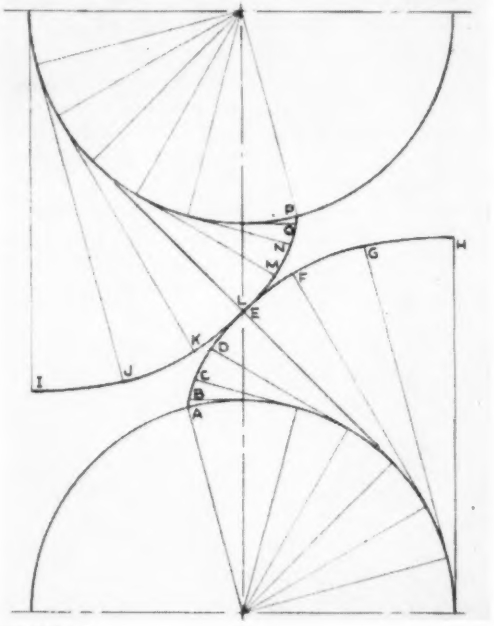
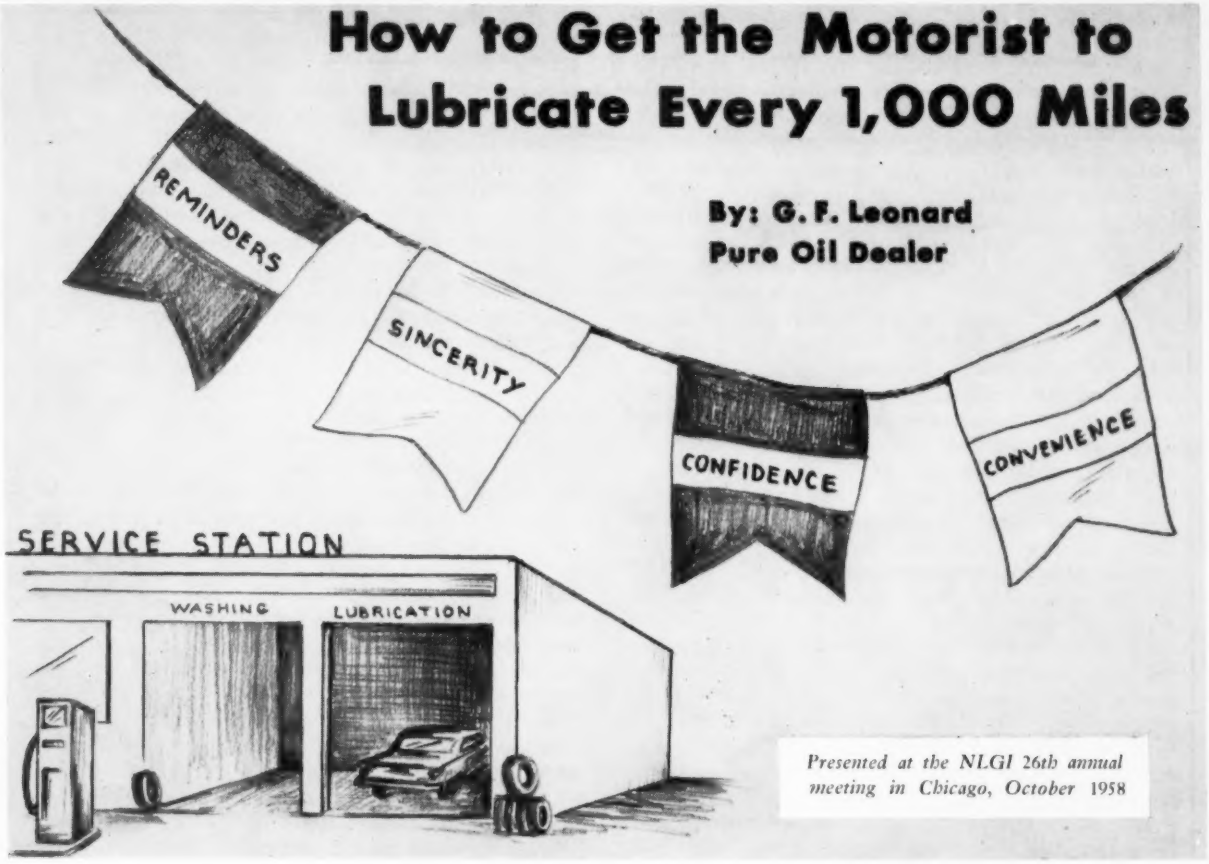


FIGURE 9

From the Service Station Dealer's Viewpoint–

How to Get the Motorist to Lubricate Every 1,000 Miles

By: G. F. Leonard
Pure Oil Dealer



Presented at the NLGI 26th annual meeting in Chicago, October 1958

HOW CAN WE get the motorist to lubricate for safety every 1000 miles? A good question. In reality most customers are not directly opposed to a 1000 mile lubrication service. Why is it, then, that they do not adhere more closely to the 1000 mile interval? The fact is, gentlemen, the average motorist doesn't realize how soon 1000 miles are put on a car–just driving around town to shop, pick up the children, visiting friends and so on. They think that mileage builds up only on long trips out of the city. Actually local driving mileage adds up fast. For example, an eight block trip to and from the local school or train station every morning and evening will alone amount to approximately four miles per day. Many customers drive 1000 miles per month with this type of driving–*but they just don't* realize it. So if we intend to sell the customer on lubricating for safety every 1000 miles, we must continually remind him how far he has driven since the last lubrication.

In 1000 miles of driving a customer will stop into a service station for gas somewhere between six and ten times, depending on his particular gas mileage. This means that the attendant has that many opportunities to remind the customer about the mileage and the need for service. The attendant must take advantage of every one of those opportunities. He must get under the hood, check dipsticks and, more important, find out how long it has been since the last lubrication. Too many attendants fall down here because they are afraid to ask. It is really not as difficult as they think. People like and expect complete service so they will not object if properly approached.

The majority of cars being driven today have outside hood releases so the attendant can automatically do the checking on these cars without bothering the customer beforehand. On the remaining cars a direct statement such as, "Release the hood, please," said with a smile, will usually do the trick. Often times, with ladies especially, an attendant can release the hood himself. A polite comment such as "I'll release the hood and check the *water and oil*," would be well here.

After getting under the hood and checking the dipstick, the attendant can sometimes, through experience of feel and smell, judge whether the oil is in need of a

change or not. Of course, personal knowledge of a regular customer will guide the approach also. But in any event he should not stop at just determining whether the oil level is high or low. If he is not positive how long it has been since the car was last lubricated he should definitely find out. He can do this very easily by asking the customer what the speedometer mileage is and then comparing it with the lubrication sticker on the door. The attendant must not be afraid to open the door and look at the sticker. If he does it in a polite, friendly way most customers will not object and will, in many cases, become very interested. If the mileage indicates a change is not needed then a comment such as "everything is okay, just checking for your safety" is in order. If the mileage is more than 1000 miles the attendant should definitely recommend the needed service with a short, safety story, tie-in. The safety story that the attendant presents will, of course, depend on the type of customer, the degree of interest shown by the customer, the time element and certain other factors. But the point is that the attendant must get the customer's confidence. The attendant must tell his customers what "Lubrication for Safety" really means. He must explain that lack of proper lubrication can lead to breakdowns, costly repairs and even highway collision. Through this means the service station dealer and his employees must build customers confidence so that he will respect their judgment and ability and trust them to make the right recommendations for service. If the attendant takes a sincere attitude versus a high pressure approach he will not find it difficult to sell the customer the needed service. Of course, there are some customers who may object because of their car manufacturer's recommendation but a short discussion on the *complete* recommendations in the manufacturer's manual regarding stop and go, short trip driving, will usually convince the customer. Many of them will bring the manual out which makes it even easier to point out the fine print recommendations. You must get the customer's confidence as you would with any other customers.

No matter how active an attendant may be on solicitation at the service station there are still some customers who slip by without lubricating at the proper interval. Therefore some other means of contact must be made with these people to pin them down for a service appointment. For that reason every service station should have an organized follow-up file system. The file should be checked every day to determine those customers over due for service. A contact should be made with them by phone or mail to remind them of the needed service and make every effort to arrange a definite appointment with them. The effort that a dealer expends on this type solicitation can pay tremendous dividends.

Probably one of the biggest problems in selling lubrication service, is the time element. It seems that car is needed every minute of the day, especially in the case of the ladies, who, incidentally, are the ones in charge of the car now. It seems that most husbands are too busy to bother with little things like a car that only cost three or four thousand dollars. However, it has been found that service station customers do eat, get their hair cut, play golf or bridge, go to church and even sleep. This is the time when the service station can give the car a complete lubrication. If a customer indicates a time problem the attendant must quickly point out that the service can be done while the customer attends to other duties. He must offer to drive the customer to his destination and promise to return the car at a specified hour of the customer's choice. Pick-up and delivery service is a must. Some dealers have successfully inaugurated overnight lubrication service wherein the car is picked up and serviced while the customer is at home sleeping. The point is, gentlemen, we must make it convenient for the customer to have his car serviced.

So, in summary, let me say that if a service station dealer is going to get his customers to lubricate for safety every 1000 miles –

–he and his employees must continually, at every opportunity, remind the customer how many miles he has driven since the last lubrication.

–they must adopt a polite, friendly and sincere attitude in seeking mileage information or making service recommendations.

–they must build the customers confidence in their judgment and ability so that the customer will trust and accept their service recommendations.

–they must make it convenient for the customer to have his car serviced.

–In short, if we remind them often and remind them in the right way, we can, and will, get customers to lubricate for safety every 1000 miles.

About the Author

G. F. Leonard *became a service station attendant for the Keystone Oil company of Chicago in* 1930. *In* 1931 *the Keystone Oil company was taken over by the Pure Oil Products company, where he was re-assigned as a sales promotion man, opening new company outlets in the Chicago area. During the World's Fair in Chicago he managed the Edgewater Beach Pure Oil station and parking lot across the street from the Edgewater Beach hotel. In* 1934 *he opened the new Pure Oil station at* 692 *Central avenue in Highland Park as a lessee dealer, and is currently operating in a recently remodelled station at this same location. Mr. Leonard is one of the very highly regarded business men in Highland Park and is considered as one of the most successful Pure Oil dealers in the company.*

Technical Committee Column

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Mr. L. C. Brunstrum of Standard Oil Company (Indiana), formerly vice-chairman of the Technical Committee on Fundamental Research, took on the chairman position when Dr. J. J. Kolfenbach of Esso Research & Engineering Company resigned last year. The new vice-chairman is Mr. E. L. Armstrong of Socony Mobil Oil Company, Inc. The Technical Committee on the NLGI Research Fellowship has been discharged and its responsibilities have been added to those of the Fundamental Research Committee.

J. J. Dickason

A picture of Mr. L. C. Brunstrum of Standard Oil Co. (Indiana), chairman of the Technical Committee on Fundamental Research can be found on page 61. A picture of Mr. E. L. Armstrong is not yet available.

R. K. Smith

In accordance with approvals received at the 1958 Annual Meeting, organization of two new committees has been started, i.e., the Technical Committee on Gear Lubricants and the Technical Committee on Manufacturing Procedures and Equipment. These designations are tentative. The latter may be changed to Technical Committee on Manufacturing Operations. The first chairman of the Technical Committee on Gear Lubricants is Dr. R. K. Smith of E. F. Houghton & Co. The first chairman of the latter is Mr. J. J. Dickason of Jesco Lubricants Co. Both chairmen are recruiting members and would appreciate suggestions regarding the scope which their committees should cover in order to be of most service to NLGI in their respective areas of activities.

The Technical Committee on Manufacturing Procedures and Equipment is particularly anxious to set up its organization because they have been requested to conduct a half-day session on manufacturing problems at the next Annual Meeting in New Orleans. They will be following the pattern adopted by the new Technical Committee on Fundamental Research who kicked off their first annual meeting with a Symposium on Rheology of Lubricating Greases last October in Chicago.

27th Annual Meeting

NATIONAL LUBRICATING GREASE INSTITUTE

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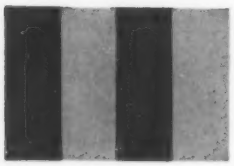

Literature and Patent Abstracts

Multi-Purpose Gear Oil Specification MIL-L-002105A (Ord)

The above specification, to be used in lieu of MIL-L-2105, was issued December 8, 1958. When this specification has been coordinated and accepted by all of the armed force agencies, it will be known as MIL-L-2105B.

To satisfy the requirements of this gear lubricant, base lubricating oils must be used which have better thermal-oxidation stability than was previously necessary. Most of the oils which will qualify are solvent refined.

Also, E.P. additives are necessary which will operate vehicle axles under conditions of high-speed and low torque as well as under low-speed and high torque.

Products meeting this specification will meet the requirements described by A.P.I. Service GL-4.

While the government does not require that this new gear lubricant be satisfactory for limited slip differentials, additives are available which are approved for this revised specification and yet will permit noiseless, vibration-free operation of limited slip differentials.

Gear Lubricants

Oxidation of Gear Lubricants—Laboratory and Field

M. J. Pohorilla and W. Hart, *ASTM Bulletin* No. 234, December 1958, pp. 45-47.

A laboratory oxidation test for automotive gear lubricants which shows correlation with limited field tests is suggested by the authors. This consists of cycling stirring and heating to 300°F. with a minimum introduction of air. Following runs up to 200 hours, viscosity increase is determined.

The test indicates the necessity of the use of additives to retard oxidation and also permits of differentiation between different additives. Graphs are used to demonstrate these facts.

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The method was also used to show that an additive developed to meet the requirement of the proposed multipurpose-type gear lubricant (API Service GL-4) develops more sludge at 300°F. than do the additives used in MIL-L-2105 type gear lubricants.

Lubrication and Maintenance of Anti-Friction Bearings

Scientific Lubrication published a special extra issue dealing with the above subject in November 1958. A digest of some of the articles which concern lubricating grease follows.

Testing Anti-Friction Bearing Greases

E. G. Ellis, pp. 14, 16, 18, 19.

After stating the essential properties of such lubricants a review is given of conventional bench and laboratory tests with some description of the apparatus used. Many of these test methods originated in the United States.

Some Practical Notes on the Lubrication of Anti-Friction Bearings

By Technical staff of the Skelfko Ball Bearing Co. Ltd., pp. 23, 24, 26-32.

In considering the use of either lubricating grease or oil it is concluded that lubricating grease should be used as far as possible in design of new applications because this offers simplified maintenance, the product does not leak from a housing as readily as oil so that machines keep cleaner, and such a lubricant offers better protection to the bearing against the ingress of dirt or moisture.

While the statement is made "that the bearing temperature with grease lubrication will usually be lower than for oil bath lubrication" provided the right grade of lubricating grease is used and design is proper, caution is given that it is not wise to pack the grease space full. When servicing anti-friction bearings, overlubrication can be

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avoided if an escape valve is present in the bearing housing. Test data indicate lower running temperatures when such valves are used.

Graphs, permitting determination of suggested intervals for regreasing such bearings, indicate that such intervals for roller bearings are shorter than for ball bearings.

The Lubrication of Anti-Friction Bearings in a Nuclear Power Station
A. J. Marles, pp. 33-37.

The major use of lubricating greases in designs now under construction is said to be in anti-friction bearings for the control rod mechanism, which operate at a temperature of about 100°C. and in an atmosphere of carbon dioxide.

Mention is made that lubricating greases satisfactory for this and some other applications in nuclear power stations have been developed and are marketed by British suppliers but no details as to composition are given.

The Effect of Quantity of Lubricant In Anti-Friction Bearings
Frank Hardy, p. 37.

Caution against both over greasing and under greasing is given and suggestions made as to how the optimum amount of lubricant for best operation can be secured. One method is to apply ample lubricant and run the bearing for a few hours to force out the excess after which a low starting torque and long life should be possible. Another suggestion, called grease plating, is to dilute the lubricating grease with a suitable solvent, dip the bearings and permit the solvent to evaporate to give a thin coating on all parts before operation.

Importance of Pumpability and Heat Stability in Industrial Greases
Wm. A. Magie, 2nd, *Iron and Steel Engineer*, 35, pp. 87-91, October 1958.

A general conclusion of the author is that a satisfactory lubricating grease for industrial use should have "a fairly uniform body under all anticipated temperatures and varying rates of shear."

This is because for such a lubricant to be used in place of oil it should be readily applied to points that are remote or hard to reach and, therefore, have only occasional attention; it should adhere to parts and be ready for immediate use on bearings which are intermittent in operation; and it should act as a seal against dirt and water and yet stay in the bearings.

It is said that: "Users are interested in examining the changes in body that occur in different type greases between 10 and 200 F when the grease is under shearing action found in actual service." Therefore pumpability in psi and penetrations are given for various types of lubricating greases at 30, 77, 150 and in most cases at 200°F. The products tested were for the most

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20°C.	0.940-0.960	Saybolt Viscosity at 210°F.	155 sec. approx.
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Moisture	0.5-1.2%	Saponification Number	100.0-116.0
Ash	0.1% Max.	Penetration at 77°F. unworked	150-180 mm/10
Melting Point	36.0°-44.0°C.	worked	340-370 mm/10
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part No. 1 NLGI Grades with the soap content varying from eight to eleven per cent and the oils in general being either 300 to 450 viscosity SUS at 100 F. A typical lithium base lubricant had penetrations of 280 at 30 F, 320 at 77 F, 33 at 150 F and 342 at 200 F. Barium and Bentone base products were slightly softer at the top temperature and one sodium base product still softer. Aluminum and calcium base lubricating greases gave higher penetrations at 150 F than did the other types of products.

The author thinks the maximum temperature at which "we can realistically expect constant operation" is 130 to 150 F for calcium and aluminum grease; 180 F for inhibited barium, lithium or sodium for a five-year life expectancy and 250 F for a six-month life expectancy. The life of various lubricating greases in electric motors operating at 280 F is given as 4000 hours for a sodium soap grease, 6000 hours for a silicone grease and 7000 hours for a copper pthalocyanine silicone grease.

The point is stressed that the ASTM dropping point is not at all indicative of the temperature at which a lubricating grease can be used.

Composition

Utilization of Mixtures of Organic And Inorganic Acids in the Preparation of Lubricating Greases

Morway (U.S. Patent 2,864,766, assigned to Esso Research and Engineering Co.) describes lubricating greases in which the thickener for lubricating fluids consists of an alkaline earth metal neutralized blend of acetic acid and phosphoric acid combined with aluminum stearate.

Thus the following formulation was used:

Glacial acetic acid	14.0%
Phosphoric acid (85% concentration)	6.0%
Hydrated lime	15.0%
Aluminum stearate	3.2%
Phenyl alpha naphthylamine	0.5%
Mineral lubricating oil, viscosity 55 SUS @ 210°F.	61.3%

The aluminum stearate was dispersed in all of the oil by heating to 300°F. and then cooled to room temperature in pans. Just prior to drawing into pans, the oxidation inhibitor was added. This cooled dispersion was charged to a grease kettle and the lime added with mixing to obtain a smooth slurry. Then a blend of the acetic acid and the phosphoric acid was added to the kettle. While agitating and with no external heat the temperature rose to about 190°F. Stirring was continued until the temperature subsided after which the product was finished by passing through a Gaulin homogenizer.

Continued on page 78

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Girdler Process Equipment Division, Chemetron Corp.
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Representative—J. E. Slaughter, Jr.

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Representative—G. W. Trainor

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Jennings Road & Denison Avenue
Cleveland 9, Ohio
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Representative—W. J. O'Connell

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Representative—Malcolm M. Moore

The Lubrizol Corporation
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Representative—J. L. Palmer

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Representative—D. B. Batchelor

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Metasap Chemical Company
A Subsidiary of Nopco Chemical Co.
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The Chek-Chart Corporation
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Representative—H. Eldridge

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11 Rue du Dr. Lancereaux, Paris VIII°, France
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Institut Francais du Petrole
CMrR—Courtel, 4 Place Bir Hackeim
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Laboratoires de Recherches Purfina S.A.
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Bruxelles (N.O.H.), Belgium
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Representative—G. A. Zamboni

Phoenix Chemical Laboratory, Inc.
3953 W. Shakespeare Ave., Chicago 47, Ill
Representative—Mrs. G. A. Krawetz

Veresit—Fabrica de Productos Quimicos S.R.L.
Monasterio 271, Buenos Aires, Argentina
Representative—Dr. Alexander Erdely

A smooth lubricating grease resulted which had a dropping point above 400°F. and was insoluble in water. This had an unworked penetration of 190, a worked penetration of 210 which increased to 235 after 70,000 strokes. Removal of water from the lubricant resulted in some softening.

Ethyl, Hydroxyethyl Cellulose Thickened Lubricants

According to Hotten (U.S. Patent 2,865,858, assigned to California Research corporation) oils of lubricating viscosity can be thickened to form lubricating greases with twelve to sixteen per cent, by weight, of ethyl, hydroxyethyl cellulose. The bodying agent is dispersed by heating above 300°F. and preferably to 380 to 400° F.

In one case a mixture of fifteen grams of ethyl, hydroxyethyl cellulose and 85 grams of a California naphthenic base oil having a viscosity of 450 SUS at 100°F. was heated to 400°F. until the thickener was dispersed. After cooling, the resulting lubricating grease had a worked penetration of 235 and a dropping point of 376°F. A similar mixture was heated to 380°F. to give a final product having a worked penetration of 292 and a dropping point of 367°F. A 5-gram sample of the latter product was still intact after having been heated in boiling water for 60 minutes.

Flange Lubricant

Jones and Davidson (U. S. Patent 2,863,833) suggest a lubricant for flanged wheels, such as those of locomotives and overhead cranes, which consists of a mixture of 54 to 70 per cent sulfur, 10 to 22 per cent of graphite, 10 to 22 per cent of hydrated magnesium silicate or commercial soapstone, and 2 to 10 per cent of chlorinated diphenyl.

Compounding consists of heating the sulfur to 120 to 150°C. where it is liquid and mixing in the solids after which the chlorinate diphenyl is added. The mixture while hot can be cast into sticks which in turn are fed against the flanges to be lubricated.

Metal Amidophosphonate Lubricating Greases

Multipurpose type lubricating greases which have high temperature and work stability, low wear properties and resistance to water are described by Hotten and Johnson (U.S. Patent 2,862,882, assigned to California Research Corp.). The preferred thickeners in these lubricants are di-sodium, di-lithium, calcium or barium salts of capryl-, laur-, myrist-, or stear-amidomthane phosphonic acid.

Thus, the latter acid was formed by the following steps: first, 305 grams of paraformaldehyde were added quickly to 2400 grams of liquid "Armid HT"; then the mixture was heated to 265°F. for five minutes, cooled to 230°F. during

look to Baker for hydrogenated castor oil derivatives

TRADE NAME	BAKER'S CASTORWAX® HYDROGENATED CASTOR OIL	BAKER'S HYDROXYSTEARIC ACID	BAKER'S METHYL HYDROXYSTEARATE
Melting Point	86°C (187°F)	69°C (156°F)	50°C (122°F)
Acid Value	2.	178.	4.
Saponification Value	180.	188.	180.
Hydroxyl Value	160.	154.	171.
Heat Stability Loss of Acid Value (6 hrs. at 285°F)	NONE	24%	NONE
Loss of Hydroxyl Value (6 hrs. at 285°F)	NEGLIGIBLE	27%	NEGLIGIBLE

Whatever your multi-purpose grease requirement, Baker can supply you with the hydrogenated castor oil derivative you need. By the bag or carload, as the world's largest and most experienced producer of castor oil derivatives, we can deliver what you need when you want it.

Samples and technical data on request.

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ESTABLISHED 1857
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ten minutes and pan cooled, to give a mixture consisting of about 75 per cent stearamide; 1000 grams of this amide were added over a period of four hours to 1300 ml. of chloroform and 865 grams of phosphorus trichloride while the mixture was stirred; next 100 ml. of glacial acetic acid were added and the stoppered mixture was allowed to stand three days at room temperature; following this, most of the chloroform and excess phosphorus trichloride were removed by heating to dryness on a hot water bath to give a chloride of the phosphonic acid. This product was purified by stirring with three liters of water at 160 to 170°F. for one hour, cooling to room temperature, adding a six-fold volume of methanol, suction filtering and washing with a six to one methanol water mixture until free from chloride. A 70 per cent yield was obtained.

A lithium salt of the subject acid was obtained by treating the crude product obtained after the three-day interval with a warm water solution of lithium hydroxide and washing the precipitate with water until it was neutral and free of chloride.

A lithium base lubricating grease was obtained by heating to 500°F. for 10 minutes a slurry consisting of 23 per cent of the above salt and 77 per cent of a California naphthenic base oil having a viscosity of 1685 SUS at 100°F. The product was then pan cooled and milled through a Manton-Gaulin homogenizer at 4000 psi. The resulting lubricating grease had a dropping point of 500°F., an unworked penetration of 243, and worked penetration of 303 after 60 strokes and 347 after 100,000 strokes.

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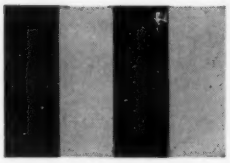


People in the Industry

Hein Appointed Special Assistant

Mr. Paul A. Hein has been appointed special assistant to the director of sales by Mallinckrodt Chemical Works, St. Louis. Prior to his new assignment, Hein was a regional sales manager supervising a region covering much of the Middle West, Southeast and Southwest.

Succeeding Mr. Hein as regional sales manager will be Mr. G. A. Wilkinson.

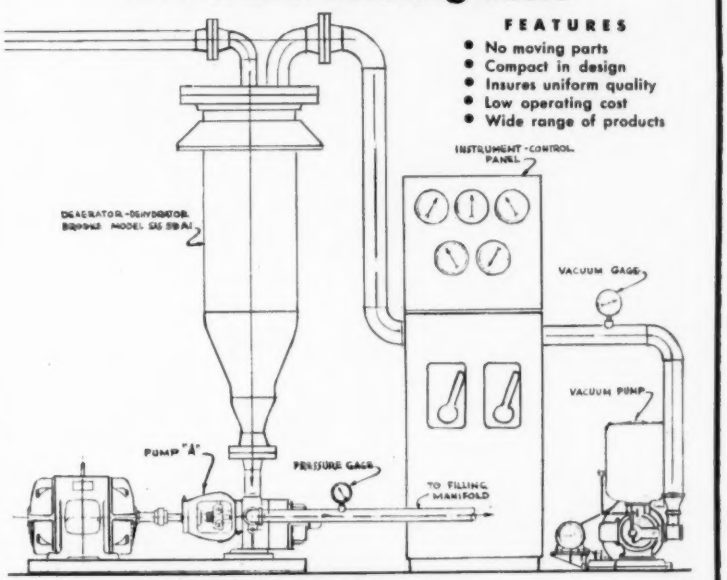
As special assistant to Mr. John E. Gaston, vice president and director of sales, Hein will be assigned special field training projects. He joined Mallinckrodt in 1911 and entered the Mallinckrodt sales department in 1922. He was made manager of city sales in 1923 and appointed regional sales manager in 1945.

Mr. Wilkinson was formerly assistant regional sales manager of the territory he now manages. He graduated from Virginia Polytechnic Institute and joined Mallinckrodt after his release from the Navy in 1945.

Darling & Company Adds to Sales Staff

Darling & Company, manufacturers of red oil, glycerine, hydrogenated fatty acids, oleic acid, and other chemical products, has an-

BROOKE DEAERATOR-DEHYDRATOR
cuts manufacturing costs



For full information write or call
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SERVICE

nounced four new additions to their sales force.

R. P. Kornafel and R. R. Jones have been assigned to the Darling office in Elizabeth, New Jersey, and will cover the eastern teritory. Darling's eastern territory conconsists of the states of New York, New Jersey, Pennsylvania, Connecticut, and Maryland.

Yockey and Titus Complete Force

J. E. Yockey has been assigned to the Southeastern territory which includes the states of North Carolina, South Carolina, Georgia, Tennessee, and Virginia. The addition of R. E. Titus to the Chicago staff completes the new sales force lineup. These new members of the sales staff represent part of Darling's expanding program of customer service.

Carter W. Hazzard

Mr. Carter W. Hazzard, vice president in charge of sales for Prairie States Oil & Grease Co., died March 24, 1959, at his home in Chicago, Illinois, after a four-month illness.

From 1924 to 1938 he was employed in the sales division, Alemite division of the Stewart Warner Corp. From 1945 to 1955 he held the position of manager, petroleum products division, Alemite division of the same company. From 1955 until his death he was vice president, sales, of the Prairie States Oil & Grease Co., Danville, Illinois.

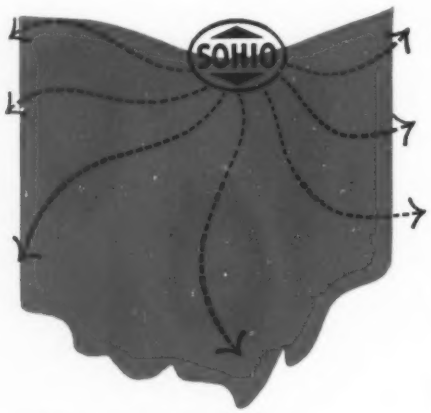
He was a veteran of both World War I and II. In World War II he served in the European theater with the rank of Lt. Colonel. He was recalled to active duty in 1951 during the Korean conflict and held the rank of Colonel in the active reserves.

Mr. Carter held a Ph.B. degree from the University of Chicago and was a former Prairie States NLGI technical representative.

Jean Louis Eugene Groff

An NLGI Technical Member in France regretfully reports the recent death of a distinguished, international authority on lubrication. Mr. Jean Louis Eugene Groff, of Institut Francais du Petrole, had a number of friends in all circles dealing with the uses of petroleum. Mr. Groff was graduated with an engineering degree in 1914 from the Institut Industriel du Nord de la France. Following graduation he served in the 1st Infantry Regiment and was awarded the Croix de Geurre.

In 1927 he first became more interested in problems of lubrication, with which he had occasion to deal in the Société des Huiles Galéna. This company was taken over shortly afterwards by the Texas Co., in whose expansion Mr. Groff played an important part. When it changed its name to Société des Raffineries de Pétrol de la Gironde



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(which has since become Caltex) he became chief engineer of its technical department.

In 1932 Mr. Groff presented his first paper on the viscosity of lubricating oils. He took active part in the World Petroleum Congress in Paris in 1937 and in the Institution of Mechanical Engineering in London. He was instrumental in the creation of the present lubricating department of the Institut Francais du Petrole. In 1944 he was awarded the gold medal of the Société d'Encouragement pour l'Industrie Nationale (Society for the Promotion of National Industry).

Mr. Groff was the author of "1' A B C du Graissage" (The A B C of Lubrication) which has worldwide distribution. He was a member of many organizations including the Institut of Petroleum (London), ASLE, SAE and the American Society of Rheology.

Lincoln Engineering Appoints Robert Doss Division Manager

Mr. Robert C. Doss has been appointed division manager with headquarters in Atlanta, Mr. John Renner, general sales manager of Lincoln, has just announced. His territory includes Mississippi, Tennessee, Alabama, Georgia, South Carolina, Virginia and the northwestern part of Florida.

Mr. Doss has been with Lincoln for four years, having been a territorial manager prior to his present appointment.

Replacing him in his previous territory is Mr. C. James Zuius, who will be territory supervisor in Georgia, South Carolina, and southeastern Tennessee. Mr. Zuius was formerly in the Detroit territory and in the service and sales department at the headquarters office in St. Louis.

J. J. Kelley to Be Purchasing Agent for Fiske Bros.

Fiske Brothers Refining Co. are pleased to announce the appointment of Mr. John J. Kiley as purchasing agent, and Mr. Bernard T. Hiney as assistant purchasing agent and traffic manager.

Mr. Kiley will fill the vacancy resulting from the retirement of Mr. H. N. Eldridge after more than 35 years of service.

Robert E. Lally Named Manager of Metasap Laboratories

Newark, N. J.—Metasap Chemical company, a subsidiary of Nopco Chemical, has announced the promotion of Robert E. Lally to the position of manager of Metasap laboratories.

In his new position, Mr. Lally will be responsible for the direction of all laboratory activities in research, development, and technical service concerned with metallic soap and vinyl stabilizer applications.

Born in Bertrand, Nebraska, Mr. Lally was graduated from Case Institute of Technology, where he received a BS degree in chemical engineering. He joined Nopco last July after 16 years in the chemical field with Ferro Chemical corporation and Chas. Pfizer and company.

Lincoln Appoints Bradley Assistant Sales Manager

Appointment of Jack Bradley as an assistant sales manager of the industrial division, Lincoln Engineering Co., St. Louis, has been announced by industrial sales manager Robert E. Crean.

Bradley, who joined the company seven years ago, has served since 1955 as Lincoln's industrial territory supervisor in Maryland, District of Columbia and parts of Delaware and Pennsylvania.

His specific responsibilities in the home office will be sales of industrial lubricant pumps and materials dispensing equipment manufactured by Lincoln, a division of the McNeil Machine & Engineering company.

Transfer grease 200 Pounds per minute!

● Designed for transfer, batching and packaging operations where grease is removed from drums, the Graco Bulldog Transfer Pump delivers up to 200 lbs. per minute of heavy grease and other semi-solid materials . . . *empties a 55-gal. drum in less than 3 minutes!*

High volume pump starts at TOP of drum, "sucks" way to bottom, cleans drum as it moves. Handles heavy greases in a fraction of the time needed by ordinary pumps. When drum is empty (right), pump can be quickly removed. *Ask for a demonstration!*

See GRACO EQUIPMENT IN ACTION
INTERNATIONAL PETROLEUM EXPOSITION
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Industry News

Emery Offers 25-Page Compilation

A new 28-page compilation of abstracts of patents and journal references on dimer acid is offered by Emery Industries. It contains abstracts of 113 United States patents and 27 published articles dealing with the use and application of the acid, which is a mixture of relatively high-molecular-weight dibasic and tribasic acids.

Fields of use covered by the patents and articles include polymers, surface coatings, urethane foams, rust inhibitors and viscosity improvers for lubricants, synthetic fibers, waxes and adhesives, among others. For a copy of the abstracts, write Emery Industries, Inc , Dept. 5, Carew Tower, Cincinnati 2, Ohio, and request a copy of Technical Bulletin No. 412.

ASTM Standards on Petroleum Products And Lubricants

This publication with 1,243 pages, hard cover, 6x9", $8.25, brings together in convenient form the various ASTM standard and tentative methods of test and specifications pertaining to petroleum products and lubricants.

There are 187 standards of which 57 have been revised, have had their status recently changed or are new in this edition. This edition supersedes the December 1957 edition and should prove most valuable to petroleum chemists, engineers, and technologists. Some of the topics covered are: crude petroleum, liquefied petroleum gases, butadiene, motor and aviation fuels, petroleum solvents, diesel fuels, distillate and residual fuels, kerosine and illuminating oils, lubricating oils, industrial oils, turbine oils, electrical insulating oils, greases, petroletums, paraffin waxes, and spray oils.

Included also as information only are fourteen proposed methods of test which are published in draft form for the purpose of soliciting comments. Such proposed methods

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Every time a service station does a lube job with Molysulfide grease, the customer gets his car back with a like-new ride. He gets a quiet ride and a smooth ride. So he comes back again and again. And each time he does, he's a prospective customer for oil, gas and the whole TBA list.

Because Molysulfide's extra tough film of protection bonds firmly to all bearing surfaces, Molysulfide chassis grease can't be squeezed out, jolted out or washed out between lubrications. It stays right in there, fighting friction for a full thousand miles. Want proof? An independent research organization made a 2-year, 2,000,000-mile road test of this new lubricant against a conventional chassis grease. They found that Molysulfide grease reduced wear on critical auto parts from 17 to 53%.

When customers ask your service stations for Molysulfide grease jobs, it pays to be ready for them.

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have not been formally approved by the society and are distinguished from the standards and tentatives by the absence of an ASTM serial designation.

Copies of this book may be obtained from ASTM headquarters, 1916 Race St., Philadelphia 3, Pa.

Alpha-Molykote Publishes Bulletin

Bulletin 120, a new two-color bulletin on Molykote wear-in compound, has been published by the Alpha-Molykote corporation, of Stamford, Connecticut.

The bulletin discusses the effectiveness of the new compound in eliminating the damage due to improper breaking-in of new or rebuilt machinery. Besides its basic use as a wear-in lubricant, Molykote wear-in compound is also an excellent lubricant for other troublesome friction applications in the average machine shop.

Ordering information, including prices, is included in the bulletin as well as photographs of the simple, two-step method of applying Molykote wear-in compound to insure positive protection gainst galling, seizing, scuffing, scoring, tearing, scratching and excessive abrasion.

Copies of Bulletin 120 are available by writing to: the Alpha-Molykote corporation, 65 Harvard Ave., Stamford, Conn.

New Wall Bracket to Hold Lube Pump

A new pump support wall bracket, designed to hold a lubricant pump off the floor while drums are being changed, has been developed by Lincoln Engineering company, St. Louis.

The bracket, of heavy 16-gauge sheet steel, zinc-plated to resist corrosion, eliminates the need for pump elevators or hoists. The operator merely hooks the drum cover flange on the bracket while he slides in a fresh drum of lubricant. Since the pump tube is held free of the floor, it cannot be contaminated by dirt.

The bracket includes two mounting holes, top and bottom, for securing to any type surface with 5/16" diameter bolts or screws.

The new brackets are available from Lincoln lubrication equipment distributors throughout the country. For additional information write for bulletin 540.

New Mobile Display Unit

The Aro Equipment corporation, Bryan, Ohio, will spearhead its 1959 lube equipment sales program with a new mobile display unit. It is named the M-D, and is the first unit of its kind in the lube equipment market. The M-D is a

Meet your steel container problems head on! Make VULCAN your prime source for STEEL PAILS AND DRUMS!

Vulcan's stock of full open head and tight head pails assures prompt shipment of all popular styles and sizes! Huge warehousing facilities enables Vulcan to fill your pail needs **fast** . . . whether you order a carton, a truckload, or carloads.

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See "Pails" and "Drums" in the Yellow Pages
Representatives in all Principal Cities

IOCA Will Meet in Chicago

The Independent Oil Compounders association, with headquarters in Kansas City, have announced the location of their twelfth annual meeting.

Chicago will be the locale and meeting dates will be Sunday, Monday and Tuesday, September 27, 28, 29, 1959. The IOCA session will be held at the Pick-Congress hotel.

Selection of Chicago as a convention site was made after a survey showed a majority of members favoring the Windy City, Mathews said. A listing of IOCA meeting speakers will be given in a later issue.

custom-built van fitted with basic equipment recommended for a modern lubrication department. A built-in generator and compressor allows this equipment to be operated instantly, without need of an outside power source.

Aro believes that the M-D finally overcomes many of the problems involved in field sales meetings and demonstrations. Conventional field demonstrations usually require elaborate preparation. A room must be located and then supplied with mounting facilities and a compressor. The lube equipment itself must then be trucked to the location, carried into the building and carefully installed. Visitors who are asked to attend such a meeting must often sacrifice considerable time to do so.

By contrast, the M-D is ready for demonstration anywhere, whether in a parking lot or alongside the curb. The interior of the van will accommodate six men comfortably. Weather is no problem, since the M-D carries its own climate in an air conditioner and heater. An electric refrigerator and coffee maker allow refreshments to be served.

Chek-Chart Announces 1959 Lubricant Recommendations Booklet

Publication of the 1959 edition of the Lubricant Recommendations booklet has been announced by the Chek-Chart corporation.

The booklet is packed with information that is essential to everyone engaged in a business wherever motor oil or gear lubricants are made, sold, or applied. It particularly serves as a source of vital information for stationmen, tank truck salesmen, and oil company sales personnel and distributors.

To provide the latest approved information and the most complete make and model coverage, this handy pocket-size booklet contains complete motor oil and gear lubricant recommendations, plus crankcase, transmission, differential, and cooling system capacities for passenger cars, trucks, and farm tractors. Anti-freeze protection tables are also included in the cooling system section.

Additional information and prices may be obtained from the Chek-Chart corporation, 33 East Congress Parkway, Chicago 5, Illinois.

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Liquid	Liquid	Solid
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Other metallic soaps made to your specifications. Our Technical Staffs are available to help you adapt these products to your specific needs.

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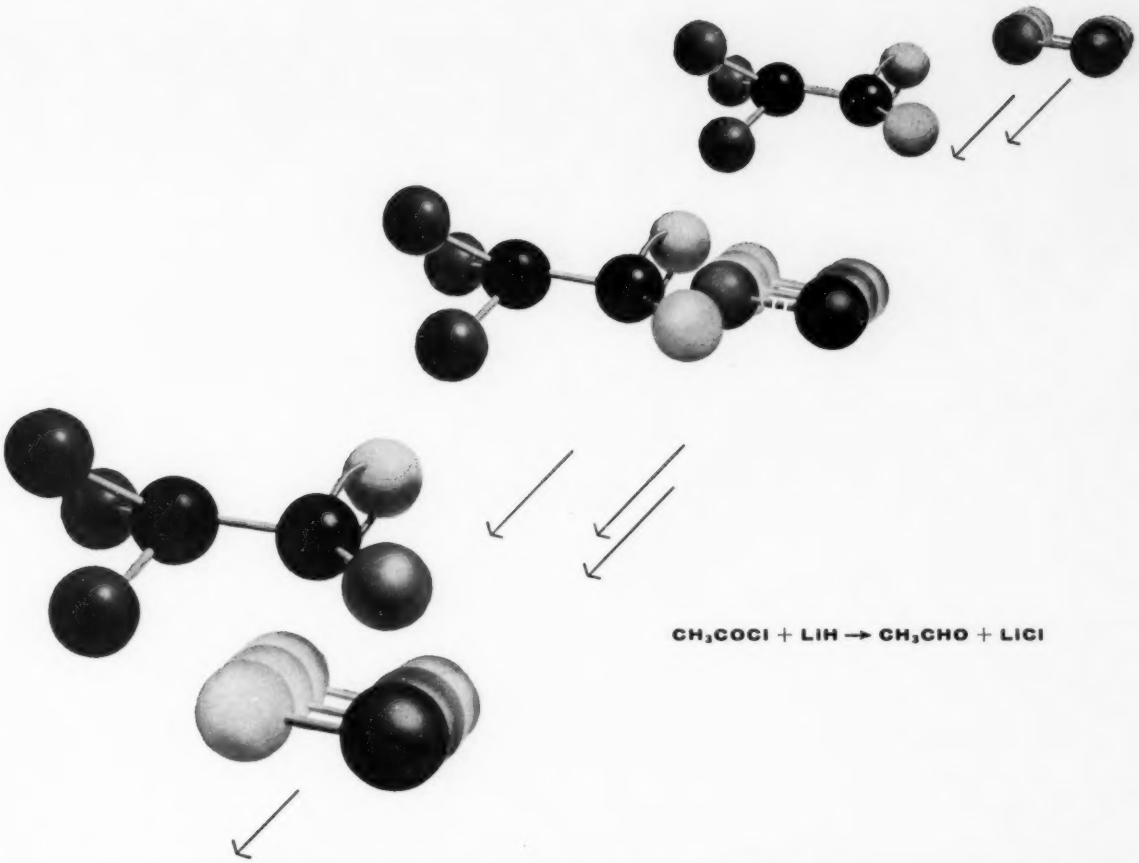


$CH_3COCl + LiH \rightarrow CH_3CHO + LiCl$

making the most of lithium hydride

Lithium hydride is one of the most versatile metal hydrides available to the chemist. Long known for its unique solubility properties as compared with other alkali metal hydrides, this lithium compound has amassed an impressive number of applications—both present and future—that go far beyond original expectations. A few examples are in order:

. . . as a reducing and condensing agent

Lithium hydride can convert carbon dioxide to free carbon . . . can reduce acetyl chloride to acetaldehyde and lithium chloride (illustrated above) . . . can be used to prepare new hydrides which would otherwise be unobtainable except in small yields and by difficult synthesis . . . functions efficiently in many organic condensation and reduction reactions . . . and can easily be increased in solubility or controlled in reactivity by conversion to mixed hydrides.

. . . as a catalyst

Lithium hydride reacts with alcohols to form lithium alcoholates and hydrogen. This reaction makes possible the convenient preparation of anhydrous lithium alcoholate which is useful as an alcoholysis catalyst.

. . . as a hydrogen bank

Lithium hydride is an ideal source of hydrogen . . . just one pound of lithium hydride will generate as much as 45 cubic feet of hydrogen gas at S.T.P. This gives you more hydrogen per unit of weight than can be secured by using "bottled" gas in steel containers.

. . . as a nuclear shielding material

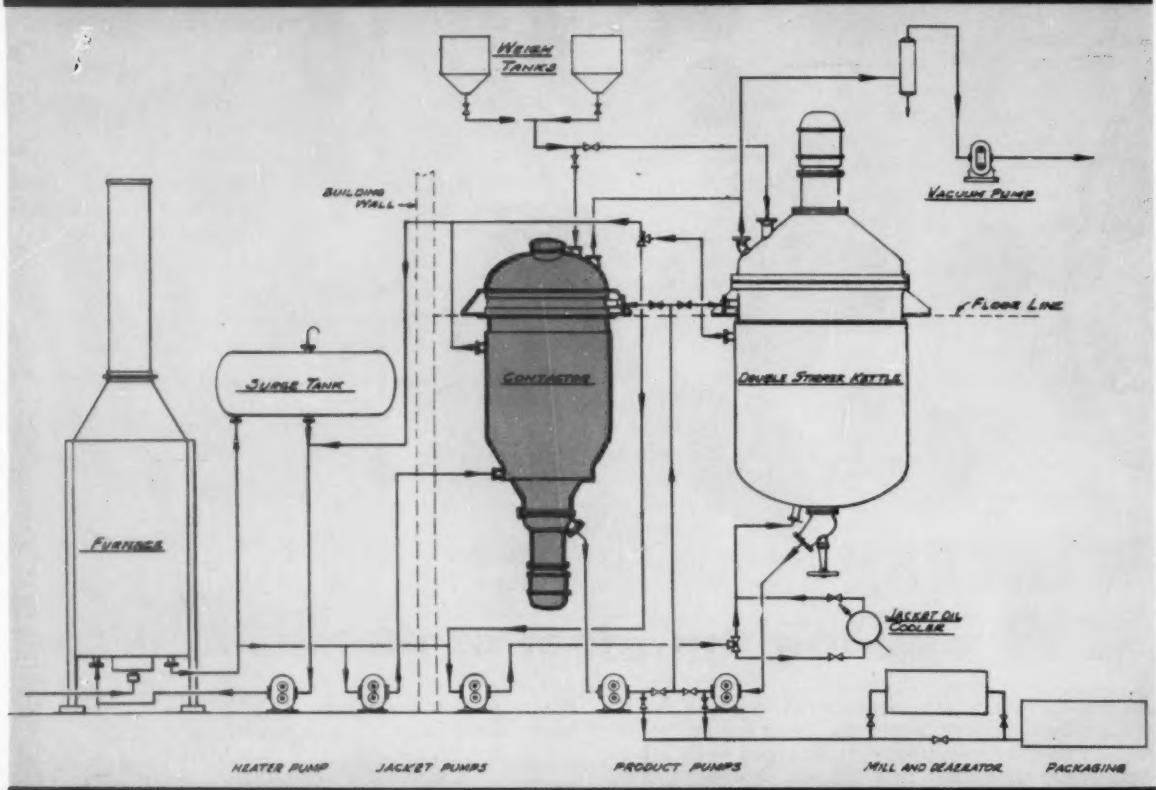
N_H of lithium hydride is 5.90 compared to 6.68 for water at room temperature. And because of its low dissociation pressure at its melting point (27 mm at 680°C.), lithium hydride can be heated to red heat in a thin-wall container . . . without requiring a pressure shell. It appears to be stable indefinitely at this temperature.

These and many other useful characteristics of lithium hydride may help improve your product or process. For complete technical data, write for Bulletin 102. Address request to Technical Literature Dept., Foote Mineral Co., 402 Eighteen West Chelten Bldg., Phila., 44, Pa.

FOOTE MINERAL COMPANY

LITHIUM CHEMICALS, METAL, MINERALS • STRONTIUM CHEMICALS • WELDING GRADE FERRO ALLOYS • ELECTROLYTIC MANGANESE METAL • STEEL ADDITIVES • COMMERCIAL MINERALS AND ORES • ZIRCONIUM, TITANIUM, HAFNIUM IODIDE PROCESS

The STRATCO contactor



and How It Simplifies Grease Making

The Stratco contactor is a highly efficient mixing device and when combined with the heating and cooling system shown above provides extremely close control of reaction temperature. With intimate contact between reactants and controlled temperature, very short batch time cycles are required.

Compared with other systems, Stratco grease plants produce more uniform greases with less soap and require less laboratory control.

A complete Stratco plant layout is illustrated above. Equipment is adaptable to modernization programs as well as new installations. Specific equipment recommendations made without obligation.

STRATFORD ENGINEERING Corporation

612 West 47th St. — PETROLEUM REFINING ENGINEERS — Kansas City 12, Mo.